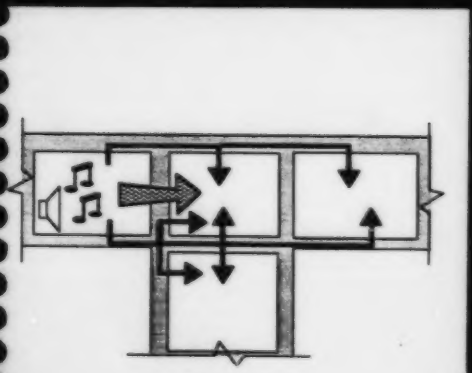
Canada Mortgage and Housing Corporation

Société canadienne d'hypothèques et de logement

BUILDERS' SERIES



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Noise Control

The material for these publications was developed in consultation with the Canadian Home Builders' Association for a series of builders' workshops held across the country.

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Aussi disponible sous le titre L'isolement acoustique

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Noise Control

Poor control of noise between apartments or noise coming into a house from outside is a common cause of complaint from homeowners.

For good noise control, proper design is essential. This guide identifies some of the causes of noise control, explains the way noise is measured and recommends several publications that provide good advice on design that will control noise.

It also points out the potential problems that will inevitably arise if good noise control design is not used, and recommends construction principles to avoid that happening.

This publication is intended only as an introduction to controlling noise in buildings. Additional information on design and construction can be found in two other CMHC publications: *Road and Rail Noise, Effects on Housing (NHA 5156) and New Housing and Airport Noise (NHA 5185).*

Sound Sources

TV sets, stereo systems, appliances and voices generate sound in buildings by making the air vibrate. The vibrations travel through the air and cause the building structure to vibrate.

Objects striking the structure, such as footsteps or plumbing pipes, or vibrating machines in direct contact with it — washing machines or refrigerators, for example — also cause vibrations, which travel throughout the building structure. Vibrating surfaces radiate sound.

Outdoor noise comes into a building usually through openings in the building envelope. The most common causes are ventilation openings (especially open windows), window glazing, and lightweight exterior wall finish. Modifying existing buildings to fix these weaknesses is much more expensive than starting with a suitable design.

Housing must satisfy municipal or provincial environmental regulations and provide occupants with an acceptable indoor environment. See the reading list at the end of this booklet for various publications on measuring and controlling noise in buildings.

Sound and Materials

The materials used in construction help reduce noise by absorbing it or by acting as a barrier and reflecting it.

Sound-Absorbing Materials

Mineral fibre, glass fibre, cellulose fibre, open cell foams and acoustical tiles are good examples of sound absorbers used in buildings. Ordinary fibrous thermal insulation is also good enough for this use. Closed cell foams such as polystyrene rigid-board insulation are not good sound absorbers.

Use sound-absorbing materials to reduce sound inside an enclosure, a wall, or a room. They work in these situations because the sound reflects from the hard inner surfaces and passes through the absorber many times. Sound-absorbing materials are not sound barriers.

Sound Barriers

To reduce sound transmission, a wall, a floor, or an enclosure must contain at least one layer of material that acts as a sound barrier. A good sound barrier is nonporous, solid, and reasonably heavy. Drywall, plywood, concrete, and glass are good examples. Sound barriers reduce the sound energy passing through them by reflecting most of it.

The most important property of a sound barrier is its weight per unit area. This is called the surface weight. In theory, any desired degree of noise reduction could be obtained by using a single layer wall that is heavy enough. In practice, this would lead to very heavy construction.

Sound Units and Recommended Acoustical Criteria for Occupant Satisfaction

Decibels

Sound is measured in decibels (dB) by a sound level meter. To imitate the human ear, the loudness of sounds is measured on a special scale in dBA.

Decibel (dB) is the common measure of sound level. It is common practice to treat decibels as units; for example: the sound level in the room is 45 dB. See Table 1.

Table 1. Typical Sound Levels

Noise Source	dB
Jet take off, artillery fire, riveting	120 or more
Rock band or very loud orchestra	100 - 120
Unmuffled truck, police whistle	80 - 100
Average radio or TV	70 - 90
Human voice at 1 m	55 - 60
Background in private office	35 - 40
Quiet home	25 - 35
Threshold of hearing	20

Decibel A - weighted (dBa)

is an attempt to more closely represent the response of the human ear by weighting the sound. The human ear is not equally sensitive to all frequencies; sound of the same level but with different frequencies will not be considered equally loud. Sound measured in dBA indicates human assessment of overall loudness.

Sound Transmission Classification (STC)

The sound transmission class (STC) classifies the average noise reduction in decibels for sounds like speech passing through the wall or floor; the higher the STC, the greater the noise reduction. Noise reduction is measured in decibels and depends on the frequency of the noise.

When sound transmission class is measured in a laboratory, the wall or floor under test separates two highly reverberant rooms. Sound energy from one room passes through the partition into the second or receiving room. Differences in average sound pressure level (in decibels) between the two rooms are used to calculate transmission loss for sixteen standard frequencies.

STC can also be measured in buildings. Placing the letter F in front of STC shows that the measurement was made in the field, that is, in a building, not in a laboratory.

A shorter test procedure gives an A-weighted level difference between two rooms which is usually within one or two points of the FSTC. Using this test ensures that no serious errors have occurred and that the sound isolation is close to the design value.

Impact Noise

Standard tests for floors give a rating called the impact insulation class (IIC). This rating, like STC, is in decibels and the higher the number the better the floor.

To measure impact insulation class (IIC) for a floor, a standardized tapping machine with five hammers strikes the floor ten times per second. Sound pressure levels (in decibels) are measured in the room below the tapping machine. The IIC contour, a standardized reference contour, is fitted to a graph of the sound pressure levels. The IIC rating increases as the protection provided by the floor against this specific type of impact increases. IIC can be determined in the laboratory or in the field. At the moment there is no internationally accepted short impact test, although one is used in France.

Table 2. ASTM Tests Used in Building Acoustics

E90	Standard method for laboratory measurement of airborne sound transmission loss of building partitions.
E336	Standard test method for measurement of airborne sound insulation in buildings.
E413	Standard classification for determination of sound transmission class.
E597	Standard practice for determining a single number rating of airborne sound isolation for use in multi-unit building specifications.
E492	Standard method of laboratory measurement of impact sound transmission through floor-ceiling assemblies using the tapping machine.
E1007	Standard test method for field measurement of impact sound transmission through floor ceiling assemblies and associated support structures.
E989	Standard classification for determination of impact insulation class.

Noise Annoyance

Noise annoyance may be caused by poor noise reduction, very low background noise levels, or very noisy neighbours. The recommendations in Table 3 are an improvement of 10 db over the requirements of the National Building Code. The levels shown in Table 3 are economically feasible and will give reasonable satisfaction in most cases, thus helping to reduce most callbacks. They will not, however, eliminate the noise resulting from a loud shouting match next door. For higher quality construction, the STC or IIC should be increased by 5. See also Table 4.

Table 3.
Minimum Recommended STC and IIC for Occupant Satisfaction for Various Structural Elements

Structural Element	Minimum Recommended STC	Minimum Recommended IIC
Party walls or floors	55	
Bare party floors		55
Carpeted party floors		65

Table 4.
Maximum Recommended Average Background Noise Levels (from heating/ventilation system or intrusive external noise).

Room	Sound Level (dBa)
Bedrooms	35
Living rooms	40
Outdoors (patio, balcony)	55

Construction Techniques for Reducing Noise

For lightweight construction that has high noise-reducing qualities, use the following techniques:

General

- Build the wall or floor as two separate layers. The heavier the layers the better the noise reduction.

Note: Very dense materials, such as steel or lead, give weight with minimum thickness. Use such unusual materials in a wall only if thickness is critical.

- Reduce structural transmission between the layers by eliminating solid contacts between them or by using correct resilient connections.

Note: An air-space, resilient metal furring, rubber, cork, steel springs, or cushioning blankets are used to reduce vibration transmission between one side of a wall or floor and the other.

- Make the cavity depth as large as practical.
- Fill the cavity to about two-thirds of its volume with sound-absorbing material (the insulation may be placed anywhere within the cavity). Any further additional material will give only small increases in STC and is not usually worth the cost. Do not overfill the cavity. See Table 5.

Note: The noise reduction for mineral glass fibre insulation about 25 mm (1") thick, used on its own, is only a few decibels.

Footstep Noise Control

For a single layer floor such as concrete, the greater the surface weight, the less it will transmit footstep noise. Weight is not enough, however. The most important factor in controlling footstep noise is the floor surface used to cushion the impact.

To reduce footstep noise transmission through floors built of wood or steel joists:

- cushion the impact with carpet, carpet underlay or vinyl flooring;
- use heavy layers, such as concrete, lightweight concrete, gypsum concrete, or gypsum board over the plywood subfloor;
- reduce structural transmission by installing resilient sound bars; put sound-absorbing material in between the floor joists.

Leaks

Sound leaks are small holes or fissures in the construction of a sound barrier, through which sound passes freely. There should be no significant leaks in a sound barrier. It should be equivalent to being waterproof.

Seal all leaks with non-hardening caulking compound (acoustical sealant). Foam tapes or ordinary duct tapes that give an airtight seal can also be used.

Flanking Sound

Flanking sound is transmitted to another part of a building by travelling through the spaces in the structure instead of passing directly through walls or floors *(fig. 1)*. In buildings, expect 3 to 5 decibels less than published STC figures, even with good design and construction, because of the presence of alternative paths (flanking paths) for the sound.

The first step to achieving good noise reduction and quietness in an apartment is to use construction methods and designs that have previously obtained good STC results. The components selected then have to be joined into a system with minimum flanking transmission.

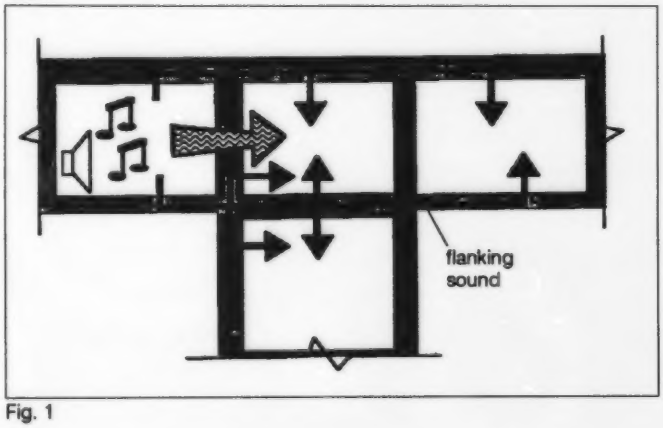

Fig. 1

Application of Noise Control Principles to Residential Construction

The following sections illustrate the application of the general principles of noise control to specific problems commonly encountered in residential construction.

Steel and Wood Stud Systems

These walls avoid rigid connections between the two sides by the use of double wood studs, wood studs with resilient metal furring on both sides, staggered wood studs, wood studs with resilient metal furring on one side, 24 gauge non-load-bearing steel studs, load-bearing steel studs with resilient metal furring on one side of them. Wood stud spacing is only important when drywall is fastened to both sides. See Table 5.

Note: Resilient metal furring should be firmly attached to the wood studs to avoid rattling. Also note that 24 gauge or thinner steel studs are resilient enough that no special measures are needed to isolate the layers of the wall from each other.

Concrete Block Construction

The STC values in Table 6 are typical for painted, parged, or plastered blocks, or blocks with wallboard directly attached to both sides. Do not use unfinished blocks as sound barriers; the STC could be considerably less than expected.

If drywall is added to blocks according to the following requirements the STC will be increased by about 8 or more. (Research needs to be done to establish the exact values.)

- Choose the method of resilient attachment from those illustrated in fig. 2.
- When drywall is used, do not paint, parge or plaster the blocks under the drywall. The untreated porous blocks will help increase the air space of the cavity.
- Use Table 7 to choose the minimum airspace between the drywall and the block. Airspaces less than the recommended minimum can actually lead to a reduction in STC or the noise reduction at low frequencies.

See Table 8 for the STC values for solid concrete walls and floors.

Table 5. Typical STC Ratings for Stud Walls Formed from Layers of 12 mm Wallboard.

	Empty Cavity Sheets of Drywall on Wall Surfaces			Sound-Absorbing Material in Cavity Sheets of Drywall on Wall Surfaces		
	1+1*	1+2*	2+2*	1+1*	1+2*	2+2*
38 x 89 (2 x 4) wood studs with drywall attached directly to both sides	33	41	43	36	44	46
90 mm (4") steel studs	39	44	50	45	49	53
38 x 89 (2 x 4) wood studs with resilient metal furring on one side	40	45	51	48	52	54
38 x 89 (2 x 4) wood studs with resilient metal furring on two sides	40	46	52	49	52	55
Staggered 38 x 89 (2 x 4) wood studs	41	47	52	50	53	55
150 mm (6") load-bearing steel studs with resilient metal furring on one side	45	51	56	56	58	61
Double row of 38 x 89 (2 x 4) wood studs with 25 mm (1") between them	46	52	57	57	60	63

* Refers to number of layers on each side of framing.

Table 6. Ratings for Concrete Block Construction

Nominal Thickness	STC for Lightweight	STC for Normal Weight
150 mm (6")	43	46
200 mm (8")	46	49
250 mm (10")	49	51

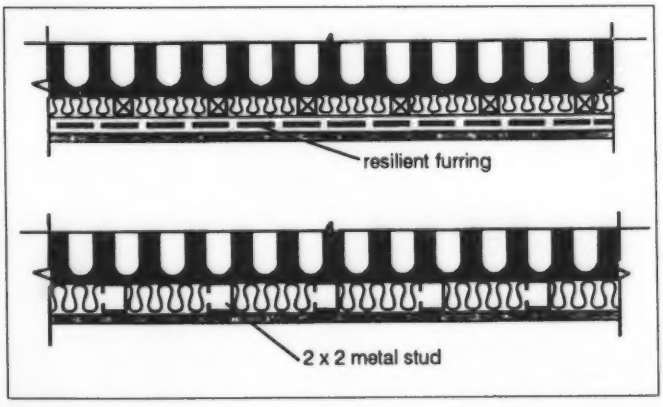

Fig. 2

Table 7. Minimum Airspace (mm) for Drywall Applied to Concrete Block

Drywall Thickness (mm)	1 Sheet	2 Sheets (same side)
12 (1/2")	60	30
16 (5/8")	47	25

Table 8. STC for Solid Concrete Walls and Floors

Thickness (mm)	Estimated STC
75 (3")	47
100 (4")	49
150 (6")	53
200 (8")	56

Lightweight Floors

See Table 9 for STC values for certain joist floors.

Table 9.
Typical Values for Wood or Steel-Joist Floors with a Single Layer of 12 mm (1/2") Drywall Mounted on Resilient Metal Furring for the Ceiling.
(The cavity contains sound-absorbing material.)

Floor	Estimated STC
16 mm plywood	48
16 mm plywood + 25 mm* gypsum concrete	55
16 mm plywood + 25 mm* lightweight concrete	58

* 25 mm is used only to illustrate the estimated STC; thicker layers would be preferable, to prevent cracking.

Estimating impact insulation class

There is not enough information available to give tables of IIC for various kinds of floors. The IIC rating is controlled by the floor covering. A thick, soft carpet and underlay will easily give IIC ratings over 65. See Table 10.

Table 10.
IIC Values for Various Floors and Coverings

Basic Floor	Floor Surface	IIC
150 mm concrete	bare, ceramic tile	25
	cushioned vinyl	35
	carpet	65
	carpet and underlay	80
Wood joist with 25 mm concrete topping, sound-absorbing material in cavity, and drywall on resilient metal furring*	parquet	35
	cushioned vinyl	45
	carpet	65
	carpet and underlay	75

* This same floor without the concrete topping will give a rating of 5 dB less.

General Problems

Noise control should be built into the construction of a building. In the following list of problems, causes, and solutions, good construction principles are cited as the best solutions. In some cases, modifications after construction may help.

Problem Too much noise from neighbouring apartment.

Cause Unknown design or construction errors.

Solution

- Have an acoustical consultant measure the actual STC and IIC ratings and the background noise and give advice. You cannot find out what is wrong until this has been done.

Problem Kitchen, bathroom and entertainment noises clearly audible in neighbouring apartment.

Cause Poor layout.

Solution

- In future, design layouts that do not place the noisy rooms of one apartment next to the quiet rooms of another.

Problem Not enough noise reduction, even though wood stud wall contains sound-absorbing material.

Cause Drywall directly attached to the wood studs on both sides.

Solutions

- Adding an extra layer of drywall on both sides will not improve the wall substantially (see Table 5). Therefore, you need to remove the drywall from one side of the wall. Then, install an independent row of studs, put more sound-absorbing material in the new deeper cavity and attach drywall to the new studs.
- Remove the drywall from one side. Attach resilient metal furring to studs. Attach drywall to the furring and seal the bottom of the drywall with acoustical sealant.

Cause

Unknown design or construction error. Existing wall cannot be disturbed. *(The two solutions provided here are in order of preference; the farther that additional layers of drywall are placed from the existing wall, the better the low frequency noise reduction will be.)*

Solutions

- Install an independent row of studs. Put sound-absorbing material in the new cavity and attach drywall to the new studs *(fig. 3a)*.
- Attach strapping to the existing wall. (Use a combination of wood strapping and resilient metal furring, or steel studs only.) Put sound-absorbing material in the cavity and attach drywall to the new outside *(fig. 3b)*.

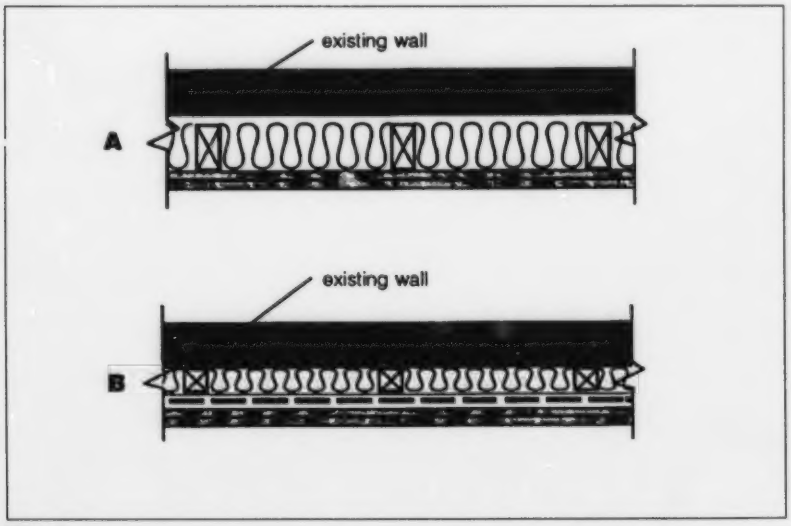

Fig. 3

Problem

Inadequate noise protection from system with drywall mounted on resilient metal furring.

Cause

Drywall screws that are too long "short-circuiting" the resilient metal furring *(fig. 4)*.

Solution

- Remove all screws that are too long and replace with shorter ones. Repair the wall. The more screws that contact the studs or joists, the poorer the noise reduction will be.

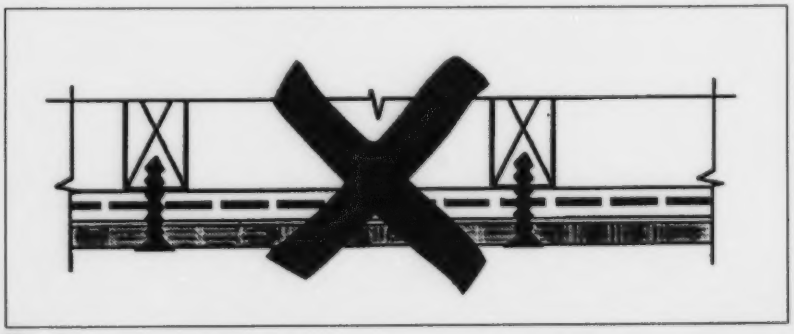

Fig. 4

Cause

Resilient metal furring between two layers of drywall (forming a small airspace) and solid connection of inner layer to studs *(fig. 5a)*.

Solution

- Do not have two layers of drywall, or any other solid sheet material, mounted closely together. Fix this system by removing both layers of drywall and the resilient metal furring. Replace the resilient metal furring on the studs or joists and re-finish the drywall *(fig. 5b)*.

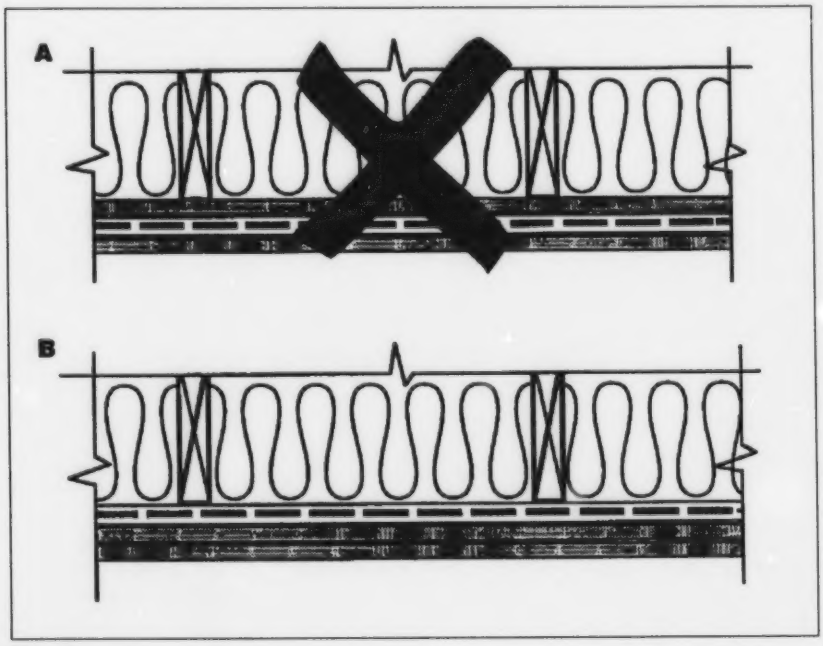

Fig. 5

Problem

Sound leaking close to the floor-wall junction.

Cause

No sealant under the sole plate.

Solution

- Be sure that sealing at the sole plate is done in one of the ways shown in fig. 6.

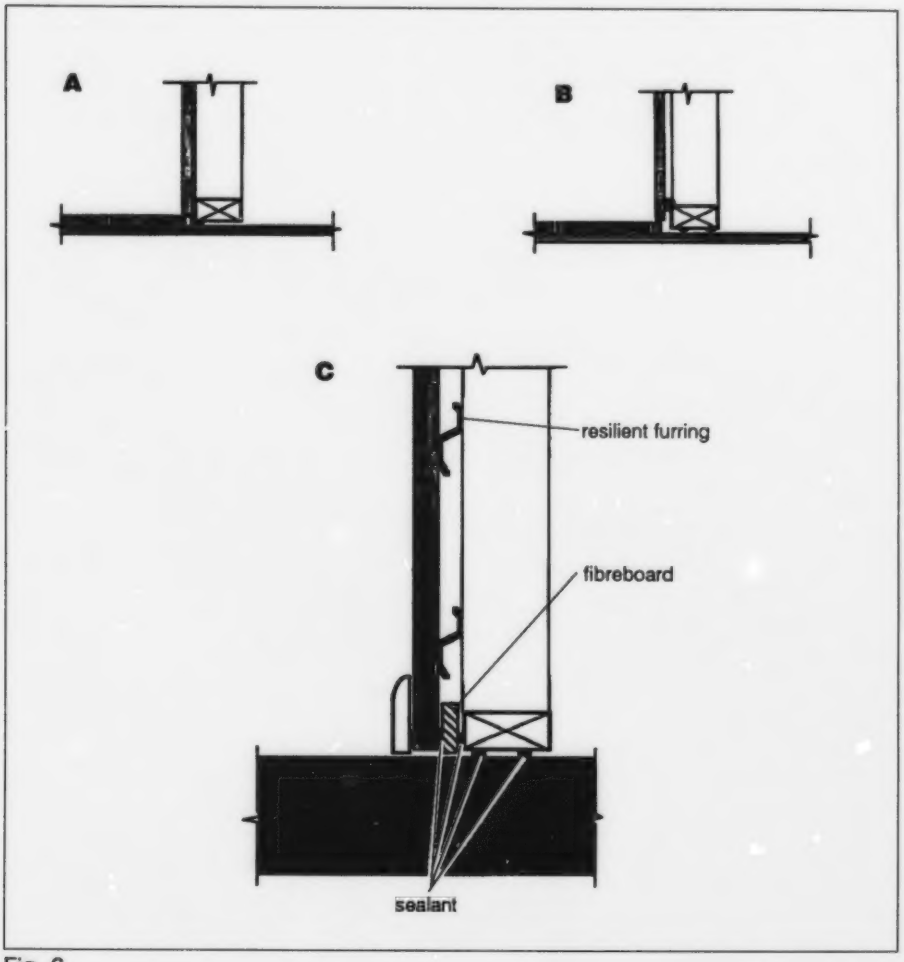

Fig. 6

Note 1: The method in fig. 6a makes it easy to verify that sealant has been applied. Unfortunately, it can make the installation of carpet messy. The method in 6b avoids the mess but it is not obvious that sealant has been installed.

Note 2: For a wall that has resilient metal furring in it, the trim can be glued on, or a strip of fibreboard or wood can be placed at the foot *(fig. 6c)*. This provides a nailing surface for installing baseboards and reduces the risk of drywall cracking because of impacts.

Cause Sealant not effective because of debris under the sole plates.

Solution

- Be sure the floor is clean before sole plates are laid. Be sure the gap under the plates is properly sealed *(fig. 7)*.

Cause Improper seal between drywall and sole plate or bottom track.

Solution

- Be sure to seal any gaps between the drywall and the sole plate before baseboards are installed.

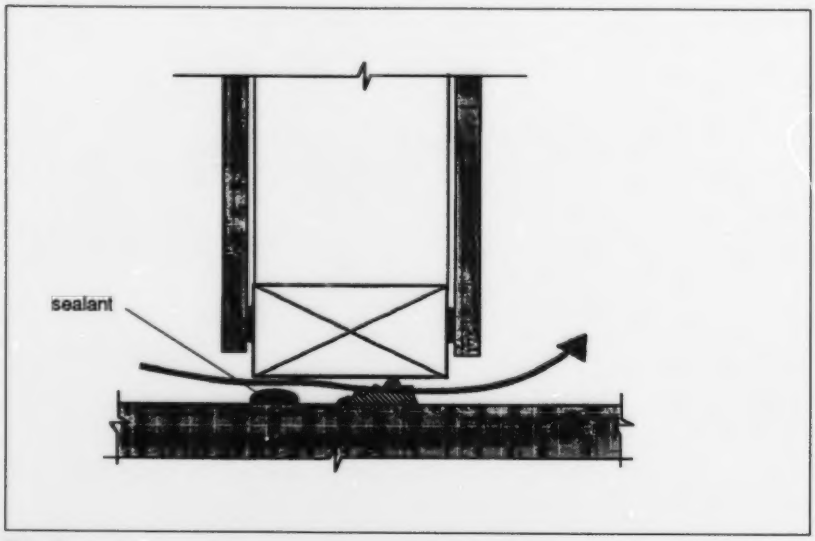

Fig. 7

Problem Sound leaking through electrical outlets.

Cause Unsealed, back-to-back electrical outlets *(fig. 8a)*.

Solutions

- In new construction offset outlets along the wall from each other as in fig. 8b. Keep holes as small as possible. Seal the openings with acoustical sealant.
- Use internal blocking as in fig. 8c. Keep holes for outlets to minimum size. Seal the openings with acoustical sealant.
- In existing housing, seal the outlets as much as possible if they have already been installed, or use foam gaskets.

Note: Extend internal blocking to guard against leaks around electrical outlets and at the foot of a double stud wall.

Fig. 8 also shows the advantage of using sound-absorbing materials inside walls and floors. The structure can be designed so that sound leaking into it has to travel through a lot of sound-absorbing material before it can leak out again.

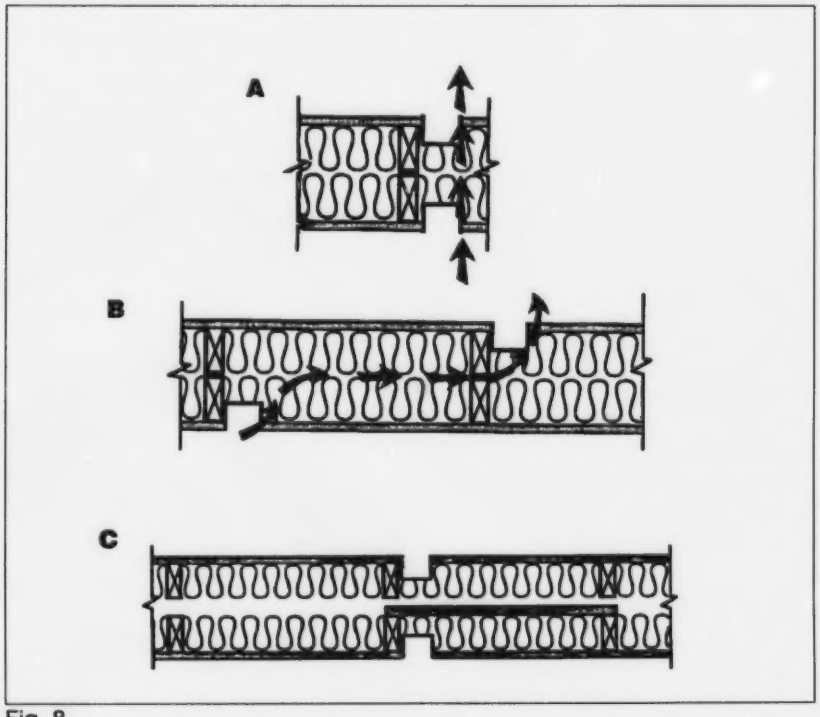

Fig. 8

Problem In existing buildings: Concrete block wall not providing expected noise reduction.

Cause Unfinished wall leaking all over. Concrete blocks are porous and will let some sound pass through.

Solution

- Seal the surface of the wall with block sealer paint, plaster or parging.

Cause No seal at foot of block wall finished with drywall *(fig. 9a).*

Solution

- Seal as shown in fig. 9b. This problem can be particularly serious if the mortar joints are not full.

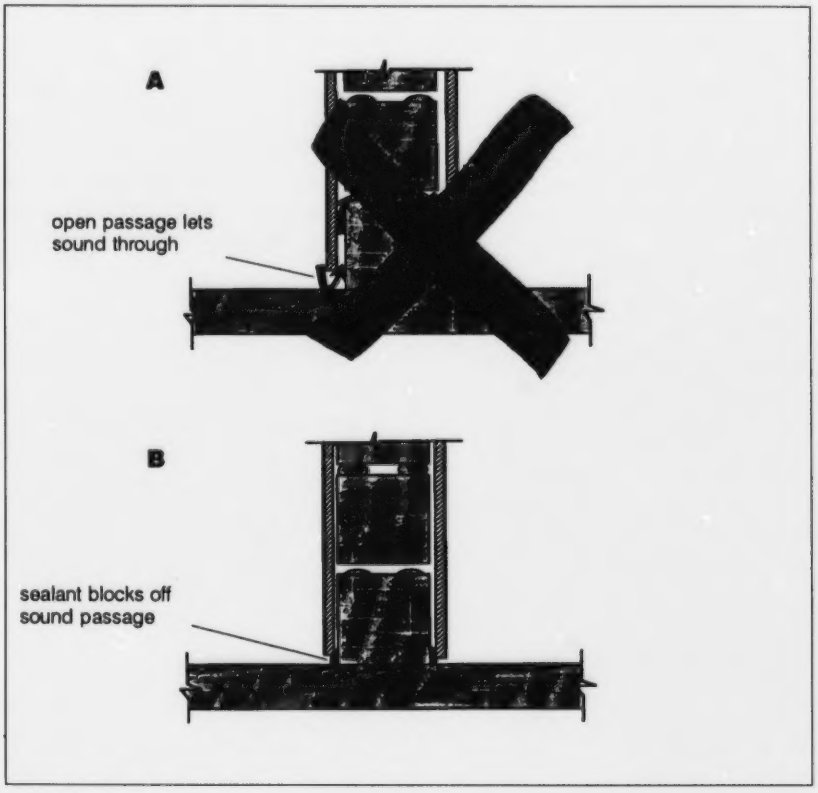

Fig. 9

Cause Drywall too close to concrete blocks.

Solution

- Fix this by adding more drywall to meet the recommendations in Table 5. Alternatively, remove the drywall and re-install *(fig. 10).*

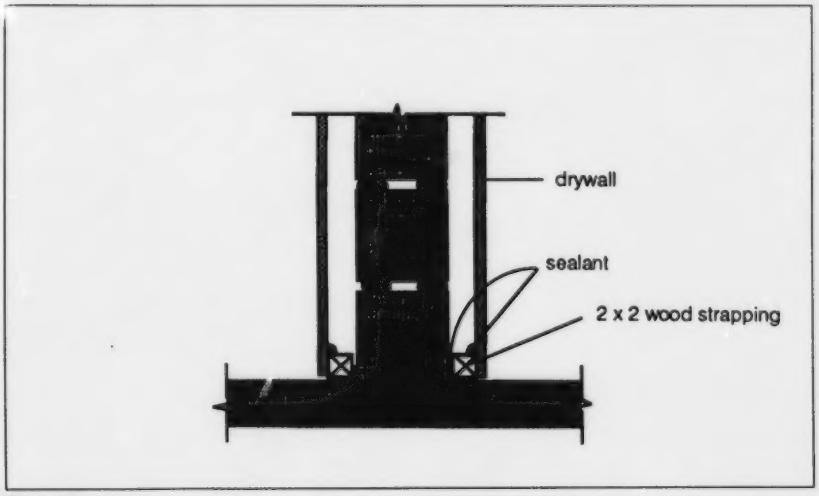

Fig. 10

Problem Inadequate noise reduction provided by poured concrete wall.

Cause Holes or honeycomb penetrations in the structure.

Solution
- Seal all obvious fissures or holes with grout or plaster before finishing the wall.

Cause Holes or honeycomb penetrations in the structure and no seal at the foot of the drywall *(fig. 11a)*.

Solution
- Seal all obvious fissures or holes with grout or plaster before finishing the wall. Seal the gap at the bottom of the drywall for extra security *(fig. 11b)*.

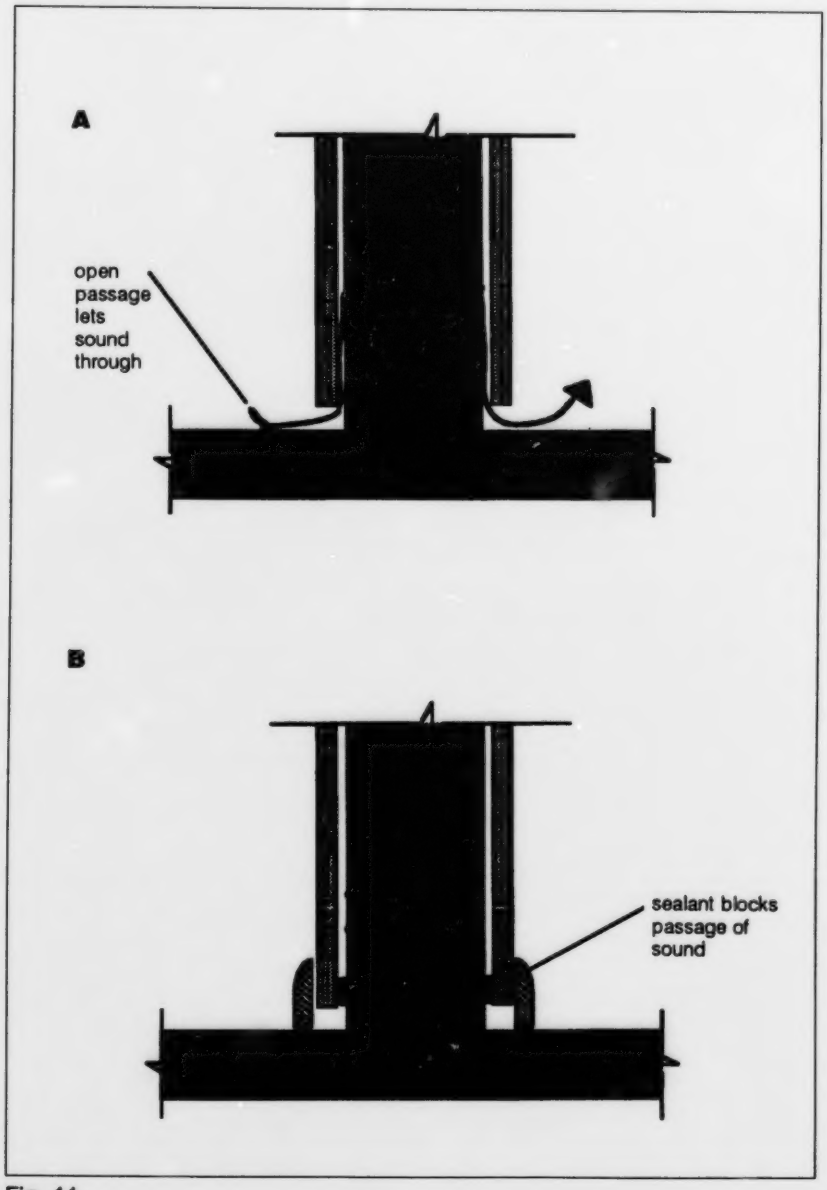

Fig. 11

Problem

Poor noise reduction from a lightweight floor system.

Cause

Ceiling directly attached to the same joists as the floor *(fig. 12a).*

Solutions

- Use resilient metal furring to support the ceiling *(fig. 12b).*
- Use separate ceiling joists to support the ceiling *(fig. 12c).*

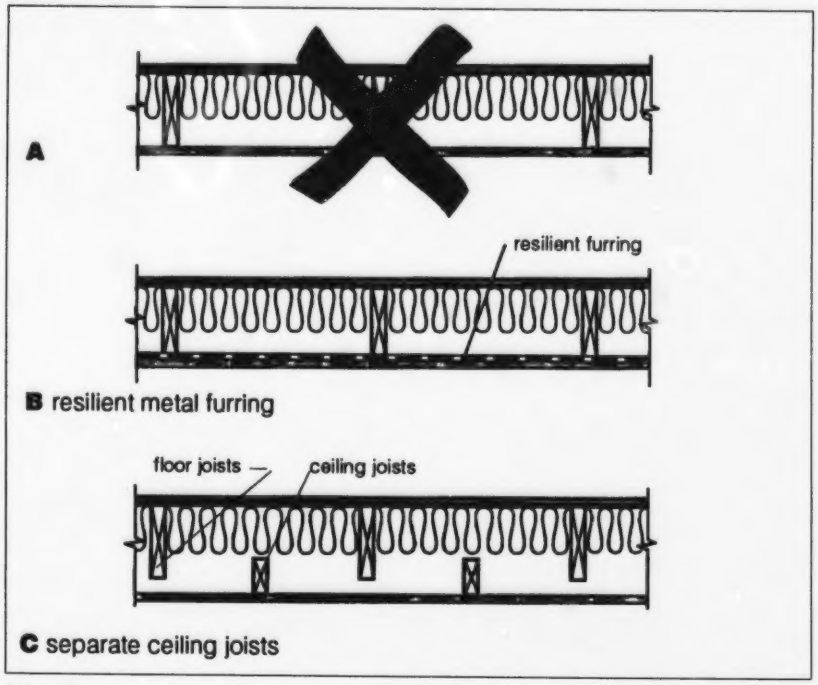

Fig. 12

Cause

Poor sealing at edges of ceiling.

Solution

- Seal wall/ceiling junction with regular tape and joint compound.

Problem

In existing building, floor with acoustical ceiling not providing enough noise reduction *(fig. 13a)*.

Cause

No effective sound barrier in ceiling.

Solutions

- Remove acoustical ceiling. Install sound-absorbing material in the cavity and drywall on resilient metal furring. Re-install the acoustical ceiling to reduce echo *(fig. 13b)*.
- Another solution would be to use gypsum board ceiling tiles and to seal them to the T bars with foam sealant.

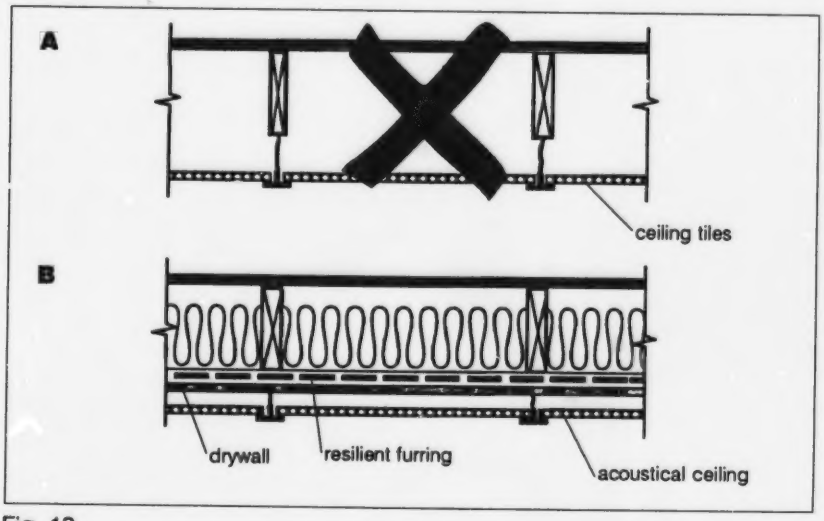

Fig. 13

Problem Floor not providing enough impact sound insulation.

Cause Upper layer not heavy enough.

Solutions

- Increase the weight of the upper floor to at least 50 kg/m2 (10 lb/sq. ft.) by adding a concrete layer or layers of drywall and plywood. Install good quality underlay and carpet.
- Install a floating floor as shown in fig. 14. A carpet on top of the floating floor will give additional protection.

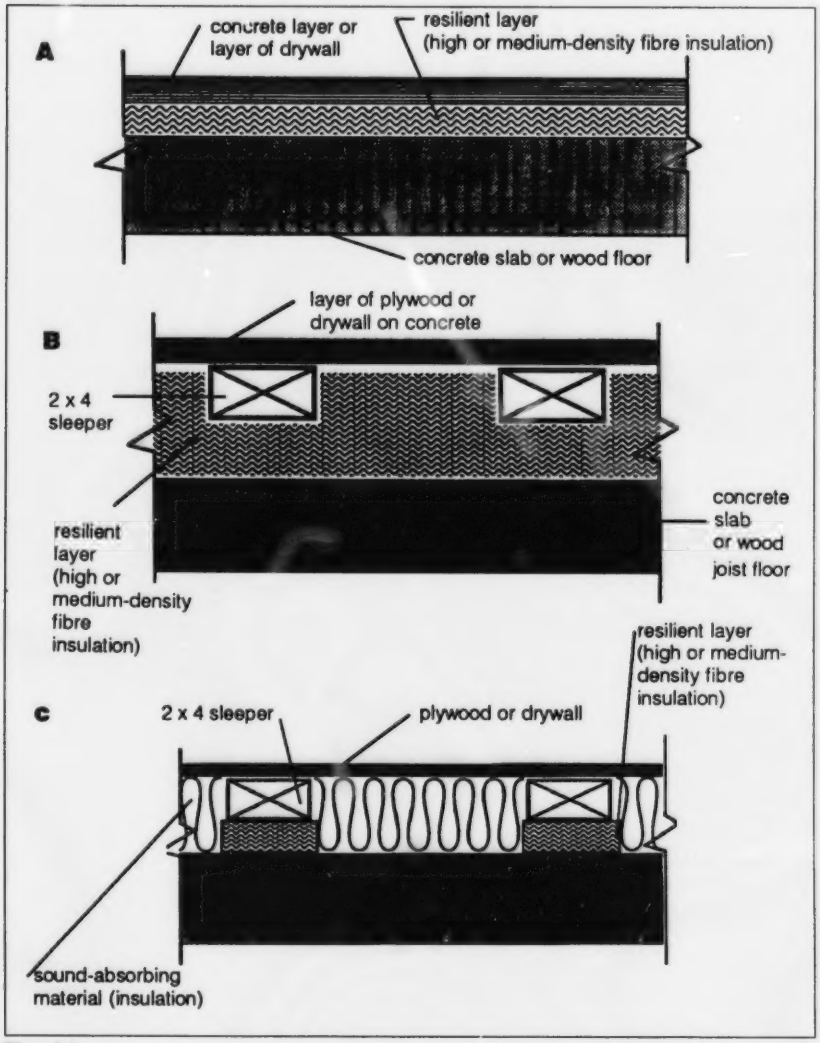
A
concrete layer or layer of drywall
resilient layer (high or medium-density fibre insulation)
concrete slab or wood floor
B
layer of plywood or drywall on concrete
2 x 4 sleeper
resilient layer (high or medium-density fibre insulation)
concrete slab or wood joist floor
C
2 x 4 sleeper
plywood or drywall
resilient layer (high or medium-density fibre insulation)
sound-absorbing material (insulation)

Fig. 14

Problem Floating floor not providing expected noise reduction.

Cause Floor contacting structure at edges.

Solution

- Stop the floating floor from touching the walls at the edges as shown in fig. 15.

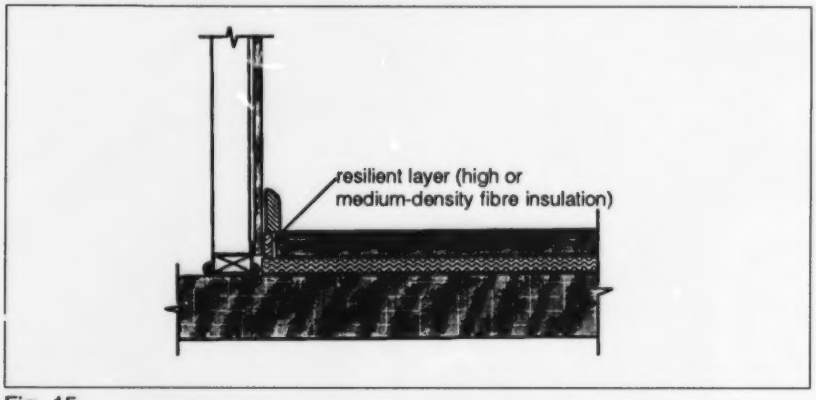

Fig. 15

Cause Nails or screws penetrating the resilient layer to contact the subfloor or joists *(fig. 16a).*

Solution

- Remove all nails or screws that are too long. Design the floor so that the top layer can truly "float" and does not need to be nailed to the subfloor.

Cause Concrete lumps or debris under the floating slab compressing the resilient layer so much that it becomes hard and transmits sound *(fig. 16b).*

Solution

- Be sure that the subfloor is level and free of debris before resilient blanket is laid.

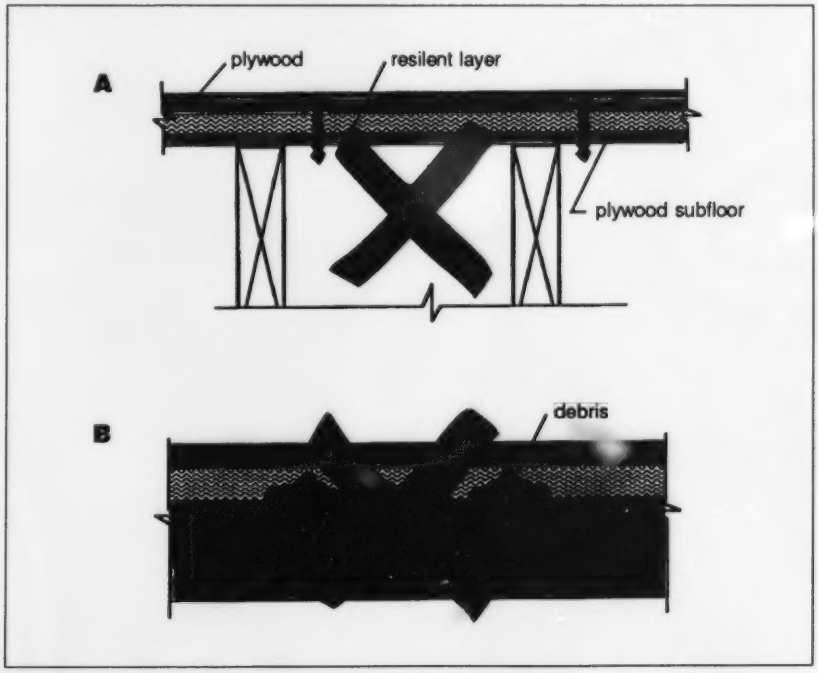

Fig. 16

Controlling Flanking Sound

Problem Good wall design but poor noise reduction.

Cause Flanking transmission along the top layer of a concrete floor.

Solutions

- Avoid floor systems that are rigidly connected under a lightweight wall. Flanking sound can travel along the top layer or in the joist to radiate in the room on the other side. Fix this by introducing a break in the structure *(fig. 17)*.
- If this type of floor construction must be used, use it only with heavy walls.

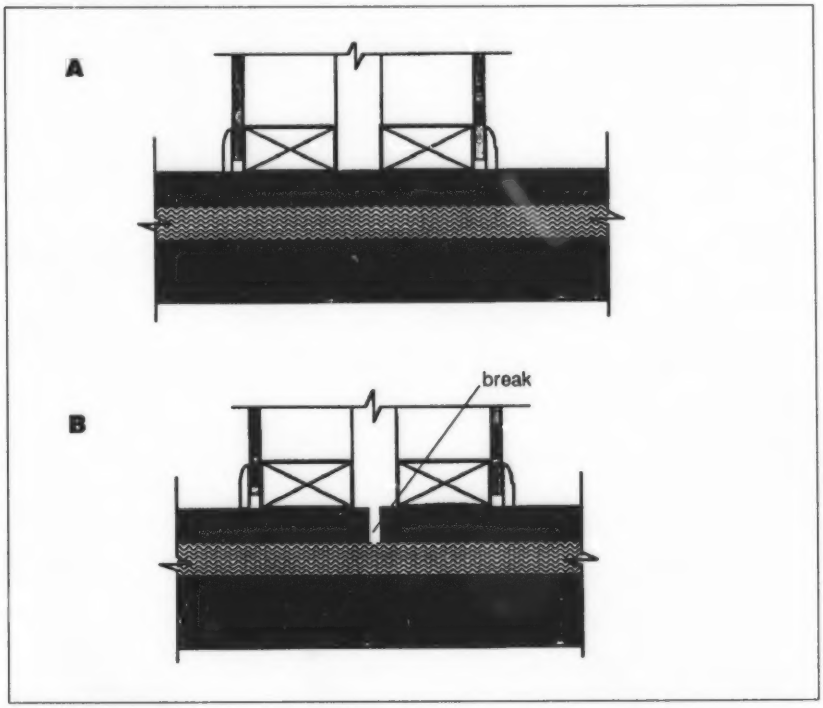

Fig. 17

Cause Flanking transmission along the top layer of a wood floor.

Solution

- Do not allow continuous layers of wood to pass under the wall. Make a saw-cut as shown in fig. 18 to prevent this happening with double stud systems. Do not use continuous joists under a party wall.

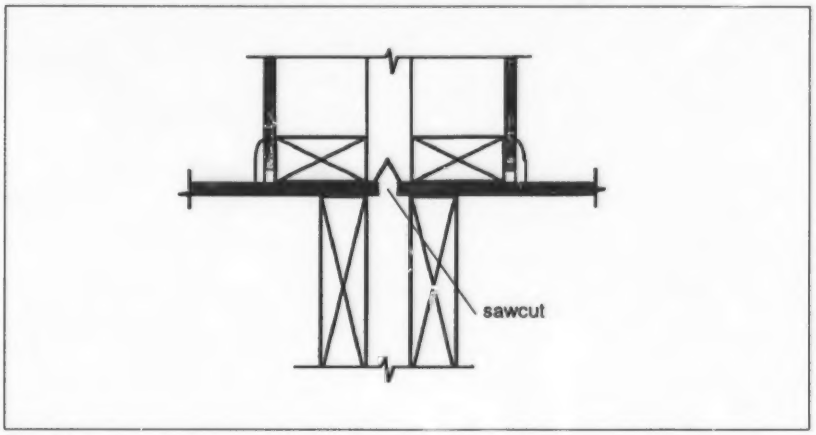

Fig. 18

Cause Transmission through floor into common cavity underneath.

Solution

- Block all openings above and below the party wall.

Cause Flanking transmission through attic space *(fig. 19a).*

Solution

- Extend party wall to the roof. *(fig. 19b).*

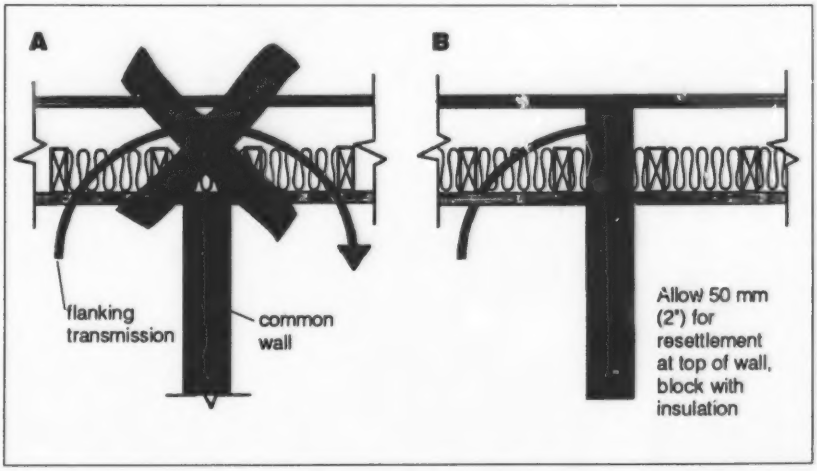

Fig. 19

Cause Flanking transmissions along single continuous layers of drywall on walls at right angles to party wall or floor *(fig. 20a)*.

Solution Make a cut in the drywall to prevent flanking transmission. Put acoustical sealant in the cut to provide an air seal on an outside wall *(fig. 20b)*.

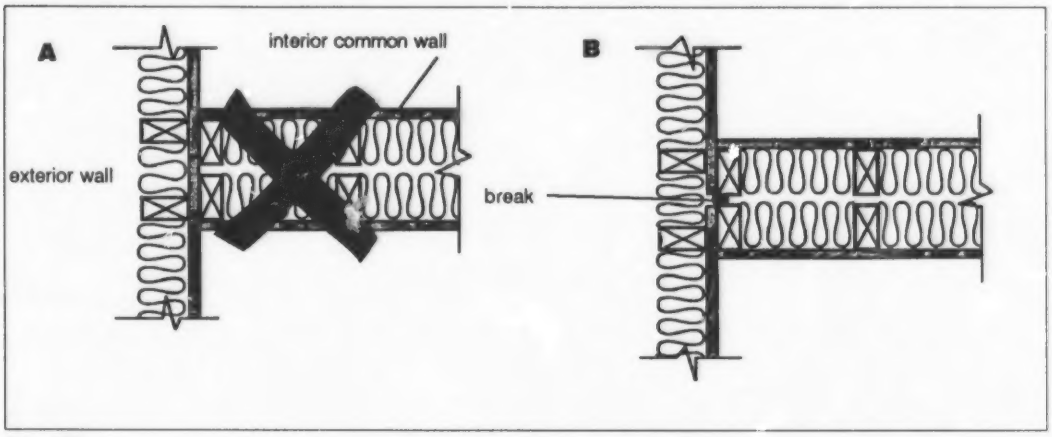

Fig. 20

Problem

Excessive noise transmission through floor, especially footstep and impact sound.

Cause Flanking transmission down walls *(fig. 21a)*.

Solutions

- Use a floating floor to reduce flanking transmission.
- Attach drywall to ceilings and both sides of walls using resilient metal furring. This reduces flanking sound traveling down the walls to the room below *(fig. 21b)*.

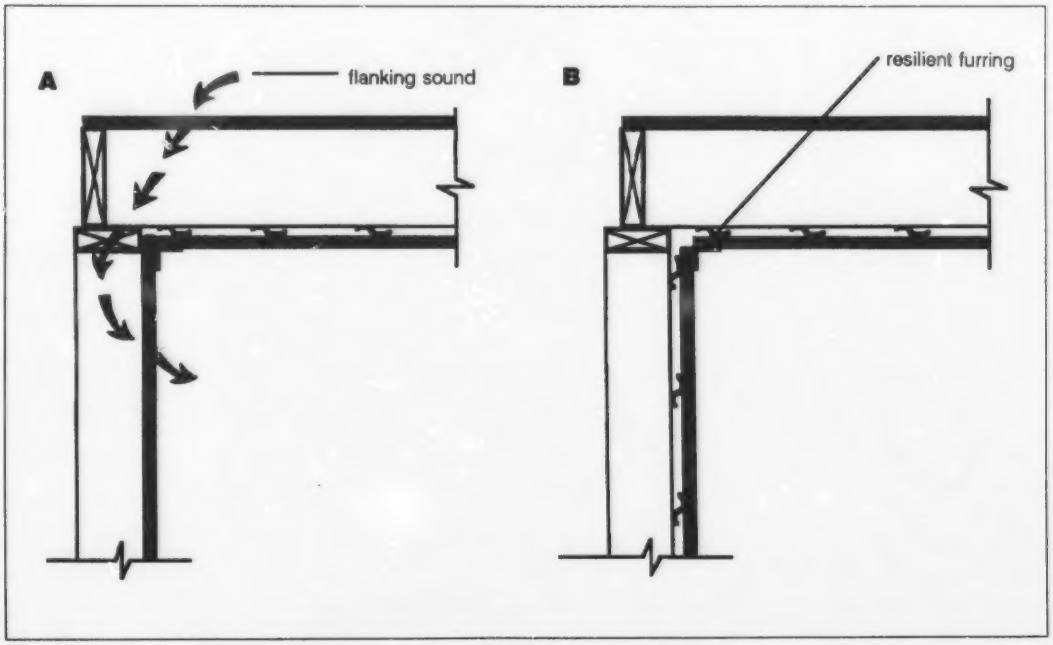

Fig. 21

Problem Sound being transmitted through hollow core precast concrete slabs.

Cause Joint between slabs not well sealed.

Solution
- Seal the joint with grout if the gap between precast slabs is large. Fill the joint with a polypropylene rope and seal with acoustical sealant.

Cause Sound is travelling through the cores from the corridors or other apartments.

Solution
- Isolate the apartment from the slab by installing a floating floor.

Problem Excessive noise transmission between bathrooms.

Cause Drywall behind baths not extended completely to the floor.

Solution
- Complete the sound barrier wall before baths are installed. If necessary, install additional drywall to install the bath *(fig. 22)*.

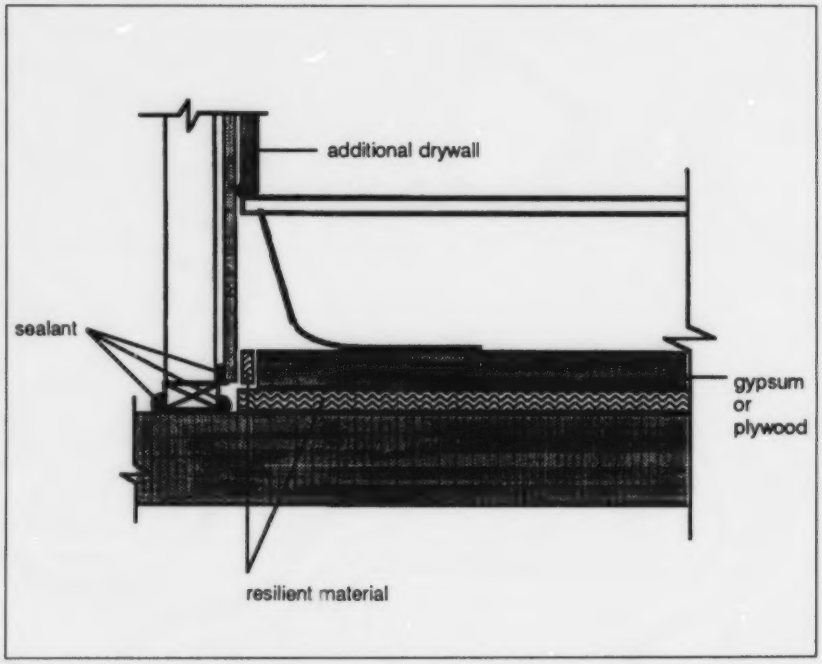

Fig. 22

Cause Bathroom cabinets mounted back-to-back on common wall *(fig. 23a).*

Solutions

- Mount cabinets on walls other than party walls.
- Surface mount the cabinets, mount them resiliently and provide them with a mechanism to close the doors gently *(fig. 23b).*
- Offset the cabinets along the party wall and provide a solid barrier such as gypsum board behind the cabinets *(fig. 23c).* Choose cabinets with a mechanism to cushion the impact when the doors close.

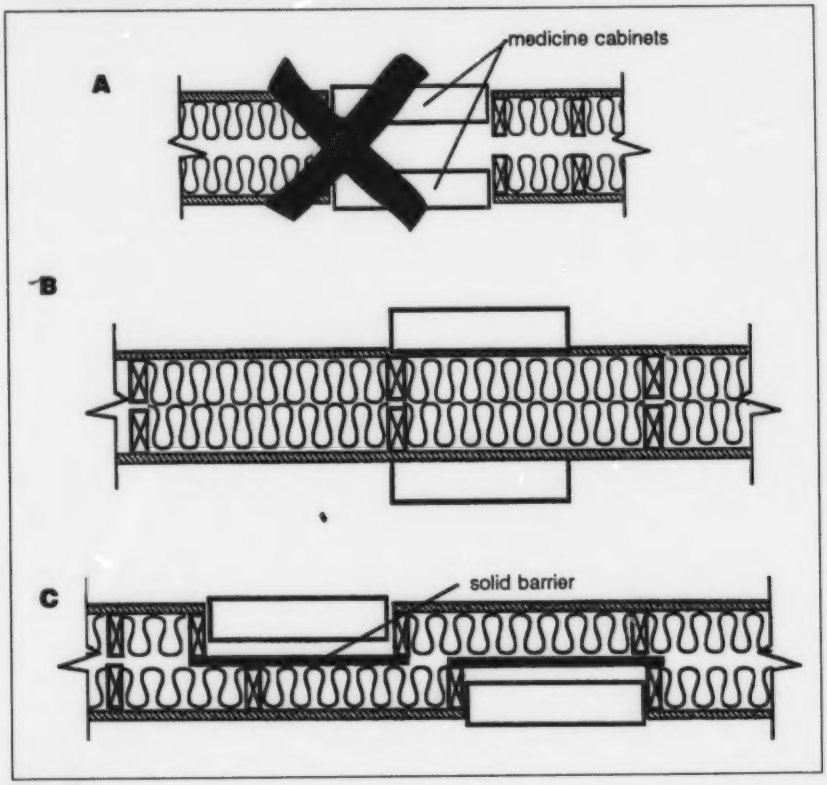

Fig. 23

Cause Leaks around pipes.

Solution

- Seal all leaks around pipe penetrations. See plumbing noise section for drawings.

Problem Footsteps on stairs clearly audible in neighbouring apartments.

Cause Stairs attached to party wall.

Solutions

- Support the stairs on a wall other than the party wall.
- Move the stairs so that they are not close to the common wall.
- Use good quality carpet and underpad on the stairs.
- In stairwells, support the stairs on structural elements that are separate from the building structure.

Plumbing Noise

Problem Plumbing noise heard all over apartment and in neighbouring apartment.

Cause Piping rigidly connected to walls.

Solution

- To avoid vibration isolate the pipe system with resilient sleeves and hangers. Avoid all rigid contact with the building structure *(fig. 24)*.

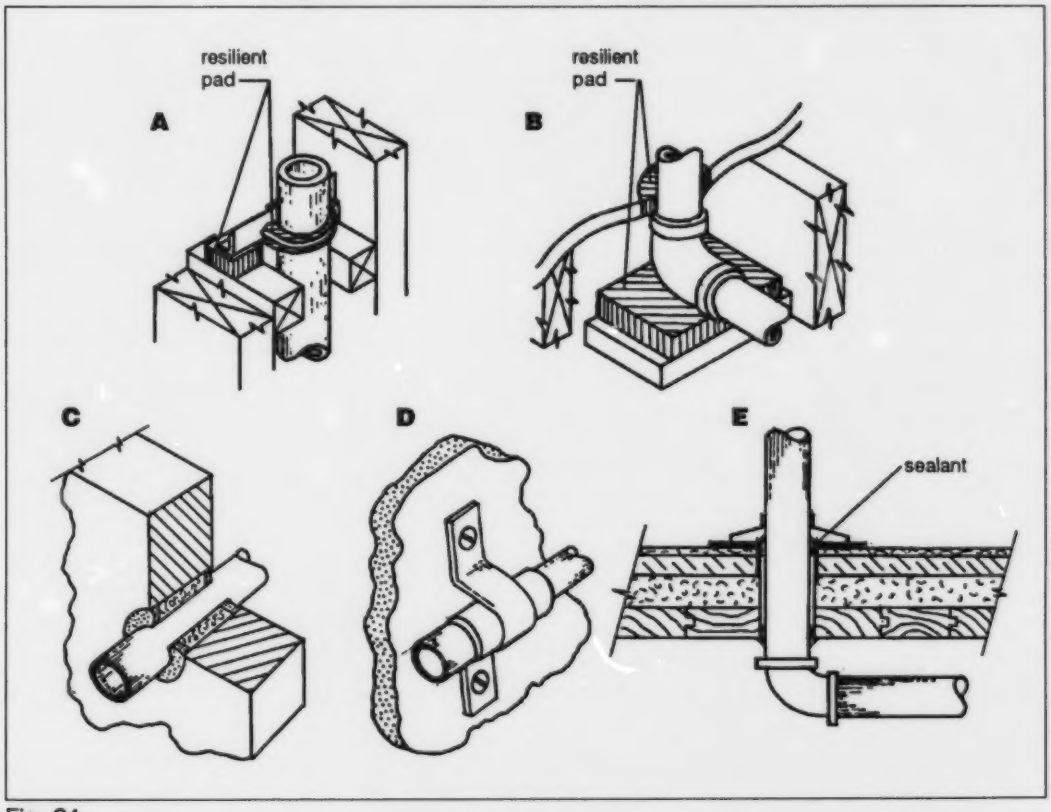

Fig. 24

Cause Turbulence cause by high water pressure, excessive number of elbows and bends.

Solutions

- Minimize the number of fittings and bends to reduce noise from turbulence.
- Use large diameter piping for all main supply lines. Limit water speed to less than 2 metres per second by use of a pressure reduction valve.

Cause Turbulence from noisy valves and fixtures.

Solution

- Install quiet valves and fixtures. Manufacturers may have information.

Problem Bath, shower and toilet noises heard in neighbouring apartments.

Cause Waste pipes installed close to quiet areas.

Solution

- Install waste pipes away from quiet areas and do not let them contact the building structure directly. Enclose them in separate pipe chases with extra noise reduction material if necessary.

Cause Bath, shower or toilet rigidly attached to the building structure.

Solution

- Use rubber, neoprene or other resilient pads to reduce vibration transmitted into the structure *(fig. 25)*.

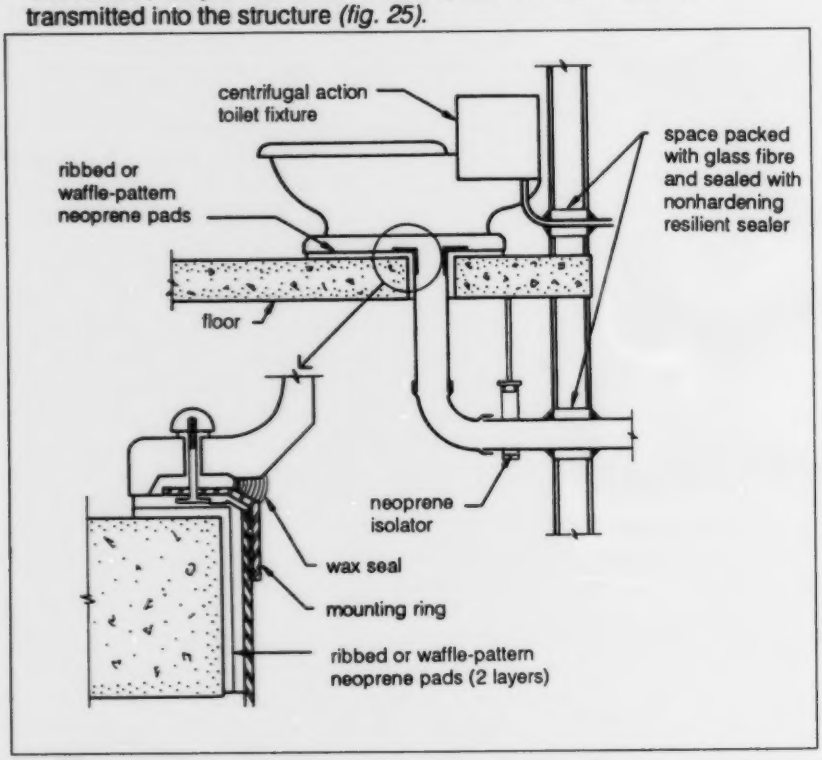
centrifugal action toilet fixture
space packed with glass fibre and sealed with nonhardening resilient sealer
ribbed or waffle-pattern neoprene pads
floor
neoprene isolator
wax seal
mounting ring
ribbed or waffle-pattern neoprene pads (2 layers)

Fig. 25

Cause A noisy toilet solidly connected to the floor.

Solution

- Install siphon-jet toilets. They are much less noisy than conventional units. Install toilets on resilient bases.

Problem

Loud banging when dishwasher and clothes washing machine valves operate.

Cause Water hammer-shock waves generated when valves close too rapidly.

Solution

- Install air cushions or mechanical bumpers right next to appliances equipped with fast-acting valves (washing machines and dishwashers, for example) *(fig. 26)*.

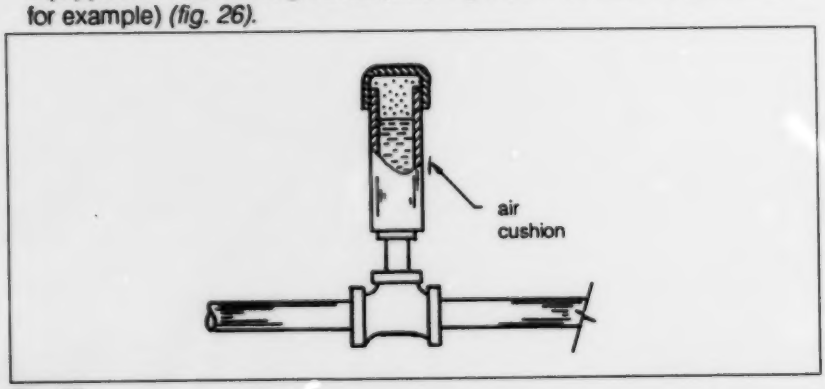

Fig. 26

Protection Against Outdoor Noise

Problem Outdoor noise penetration into homes.

Cause Windows left open to provide ventilation. At noisy sites (outdoor noise above 55 dBA), windows must be closed for acceptable noise reduction.

Solution

- Install a suitable ventilation system so that windows can normally be left closed:

- Use a forced-air ventilation system with noise control features.
- Put the inlet for outdoor air and the exhaust outlet in the quietest locations possible.
- Control noise entering through the inlet and outlet ducts by putting acoustical duct liner inside the ducts. Acoustical duct liners have rigid glass fibre lined with a cloth coating and are glued to the inside of the ducts.(See also problem on furnace noise, in the section, Noise from Indoor Appliances.)

  Note that air conditioning can easily be included in such a system for greater summer comfort.

Cause Leaks around windows or doors. (Even new weatherstripping may be badly installed or unsuitable for noise control)

Solution

- Adjust or replace weatherstripping:

- On an existing window or door, test weatherstrip by temporarily sealing with duct tape at all edges. If there is an audible change, fix the weatherstrip.
- Use multiple windows with only one operable to reduce noise transmitted through leaks.

Cause Noise transmitted through inadequate window.

Solutions

- In general, for good noise reduction:

- Use thick glass (6 mm glass, or laminated glass if thicker).
- Use as large an airspace between the glass layers as possible with the available frames. For very noisy sites an airspace of 50 to 100 mm is desirable; this is not possible with typical factory-sealed glazing.

- To improve noise reduction with existing window - add a storm window:

- Add a storm window with as large an airspace between the storm and the inner window as frame permits.
- Install very good weatherstrip on inner window if a storm window is added. To avoid condensation on the storm window, the outer window should not have very good weatherstrip.

Cause Noise transmitted through inadequate door

Solutions

- (Small effect) Use a better door.
  - Do not replace a solid-core wood door with a metal door only for improved noise control; the improvement is very slight.
  - Window panels in a door do not change noise reduction enough to matter.

- (Better) Add a storm door.
  - Install the storm door so that the space between the doors is as large as possible.
  - Install good weatherstrip on both doors. Thickness and thermal insulation performance of the storm door are not important for noise control.

- (Best) Change floor plan to use a vestibule.
  - Use a vestibule (sound lock) rather than a storm door, if much better noise reduction is needed.
  - Install the inner door with smallest possible clearance at all edges. A hollow-core wood door is adequate for most cases. A pocket door may be more convenient for some floor plans.
  - To add acoustic absorption, use carpet, closets (which will usually be full of coats), and so on in the vestibule space. Use louvered closet doors to allow sound to pass through.

Cause Noise transmitted through exterior wall.

Solutions

- Select suitable wall (if at design stage).
  For better noise reduction:
  - Use a heavy exterior surface. Brick veneer or concrete block provide more noise reduction that light metal or wood facing.
  - Reduce stiff connections between the inner and outer surface of the wall by mounting interior drywall on resilient metal furring, or using double stud construction. The air space between brick veneer and the supporting wall serves this purpose.
  - Use a double layer of drywall on the interior surface.
  - Use acoustically absorptive fibrous insulation rather than closed cell foams in exterior wall cavities.
  - Increasing the stud size from 2x4 to 2x6 improves noise reduction slightly.

- Modify wall (if too late to make major changes).
  - Mount interior drywall on resilient metal furring
  - Use a double layer of drywall on the interior surface.
  - Add a heavy exterior surface if practical. Providing enough noise reduction for a noisy site may not be possible with a lightweight exterior wall.

Cause Noise transmitted through roof/ceiling.

Solution

- Make ventilation openings as small as possible. These openings will adversely affect the noise reduction properties of the roof system.
- Locate ventilation openings on the quiet side, if possible.
- Use exposed fibrous insulation in the space between the roof and ceiling to improve noise reduction. Closed cell foam is not effective for sound absorption.
- Use a double layer of drywall on ceilings.
- Use resilient metal furring to support ceiling drywall.

Problem Too much noise in outdoor space (patio, balcony).

Cause No effective barrier.

Solution

- Put a barrier between noise source and affected area.
- Do not use hedges or trees as noise barriers. They don't reduce noise enough to matter.
- Do not use a fence with gaps between the panels. A barrier must be "solid." Earth beams, buildings and concrete walls are certainly acceptable, but lighter fences (sheet metal panels or 12 mm thick wood) are adequate for most cases.
- Make the barrier as high as possible to reduce the amount of noise bending over the top of the barrier - typical highway barriers reduce the outdoor noise by 5 to 10 dB. A row of buildings can reduce noise more because it is higher.
- Make a barrier very long, or wrap it around the protected area to avoid noise coming around the ends.

Cause Balcony exposed to loud noise source .

Solution

- Modify the balcony.
- If outdoor noise is slightly too high (55 to 65 dBA): use a solid balcony railing with absorptive surface facing balcony; apply absorptive surface treatment to underside of the balcony above, and to any other balcony surfaces, if possible *(fig. 27)*.
- Possible absorptive treatments include perforated sheet metal with fibrous sound absorber behind, and special cement/wood-fibre panels used for highway noise barriers.
- If outdoor noise is much too high (over 65 dBA): fully enclose the balcony for use as a sun porch. (If noise prevents relaxed conversation, an open balcony is basically outdoor storage space.)

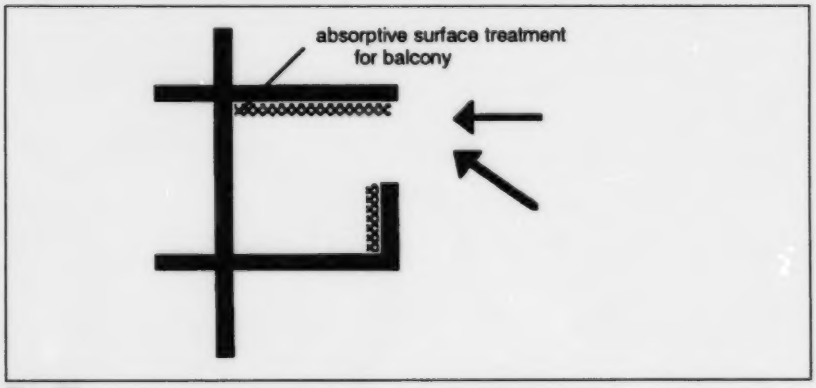

Fig. 27

Noise from Outdoor Appliances

(Heat pumps, air conditioners, pool filters)

Problem Neighbours annoyed or noise bylaw violation.

Cause Noise from appliance in a quiet neighbourhood.

Solution

- Select a quiet appliance.
- Check the local bylaw. Typical bylaws specify the maximum acceptable noise at a lot boundary, either as maximum sound level (such as 50 dBA) or relative to ambient noise (caused by traffic and other distant sources).
- Select quiet appliances by checking manufacturers' literature for a noise rating.
- Heat pumps and air conditioners are commonly rated using Air-Conditioning and Refrigeration Institute (ARI) Standard 270-1984. Typical values are from 6 to 9 "bels." For rough comparison with bylaw requirements given in dBA, multiply the ARI sound rating times 10, and subtract 20 to get the noise at 4 m from the unit.
- Do not attempt to reduce the noise output from a noisy appliance, unless it is due to an obvious fault like a rattling panel. Amateur modifications are unlikely to give much noise reduction, and may void the warranty.

Cause Appliance in poor location.

Solution

- Move to better location.
- Locate the appliance as far from property boundaries as possible, or use a barrier to reduce sound reaching a nearby boundary.
- Do not locate a noisy appliance between close-spaced buildings, or under a carport or large roof overhang. Reflections from nearby surfaces increase the noise level, and prevent barriers from working.
- If possible, locate the appliance near the corner of the home. In this location a barrier connected to the corner of the house would be effective, if needed.
- Use the procedure in ARI Standard 275-1984 to assess possible locations for noise-rated appliances such as heat pumps. This allows for effect of distance, nearby surfaces, and barriers. A similar but more complicated procedure is given in CSA Z107.71.

Cause Poor location or noisy appliance.

Solution

- Use a barrier or enclosure.
- Do not use an enclosure without expert advice that it will not interfere with normal operation of the appliance (which might void the warranty as well as reduce efficiency).
- Do not use an enclosure for a heat pump or air conditioner, if the problem is the low frequency hum heard inside an adjoining building. An enclosure is likely to amplify the low frequency hum.
- Use the procedure in ARI Standard 275-1984 to design a suitable barrier. Note that reflections from nearby walls may reduce the effect of a barrier.

Noise from Indoor Appliances

(Furnace, dishwasher, washing machine)

Problem Noise from furnace (forced-air heating system).

Cause The fan and combustion system of some modern high-efficiency furnaces are quite noisy.

Solution

- Modify the supply and return air ducts.
- Use a vibration break between furnace and major ducts to stop vibration from getting into the duct walls *(fig. 28)*.
- Fasten acoustic duct liner material (normally glass fibre with a special facing) on the inner surfaces of ducts to reduce transmission of noise along the ducts. Lining only the large ducts closest to the furnace is usually enough. Make the duct cross-section (with the lining installed) large enough for proper airflow.
- Locate the furnace as far as possible from rooms where quiet is important.

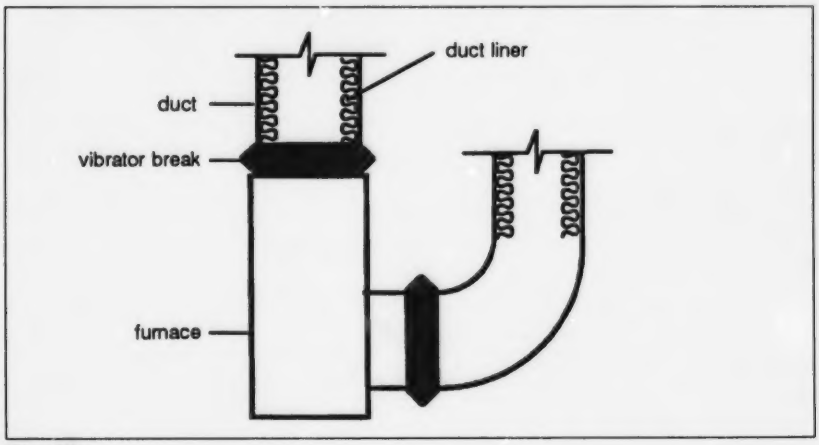

Fig. 28

Problem Ducts creak or bang when furnace cycles on and off.

Cause Expansion and contraction.

Solution

- Operate fan continuously to reduce expansion and contraction.

- Modify the ducts.
  - Put resilient pads between duct and supports *(fig. 29)*.
  - Add braces with resilient pads where panels flex. (Identify suitable locations by listening or touching).
  - Fasten acoustic duct liner to the inner face of ducts to reduce vibration of duct walls and noise transmission along the duct, as discussed above.

Cause Noisy appliances (dishwasher, washing machine).

Solutions

- Reduce transmission to other rooms.
  - Put doors on kitchen and laundry room to reduce noise reaching other rooms.
  - Locate rooms normally containing noisy appliances as far as possible from noise-sensitive areas.

- Improve the installation.
  - Put acoustically absorptive lining on inner faces of enclosure.
  - Do not connect appliance to walls or cupboards; their surfaces act as sounding boards, and radiate more noise.
  - Support any large appliance (such as washing machine) on a heavy, rigid surface like a concrete floor, if possible.
  - Use suitable resilient mounting to reduce vibration transfer into the structure. Incorrectly chosen mounting can amplify vibration; follow recommendations from manufacturer or an expert. Resilient mounting is much less effective on flexible floors (such as plywood on wood joists).

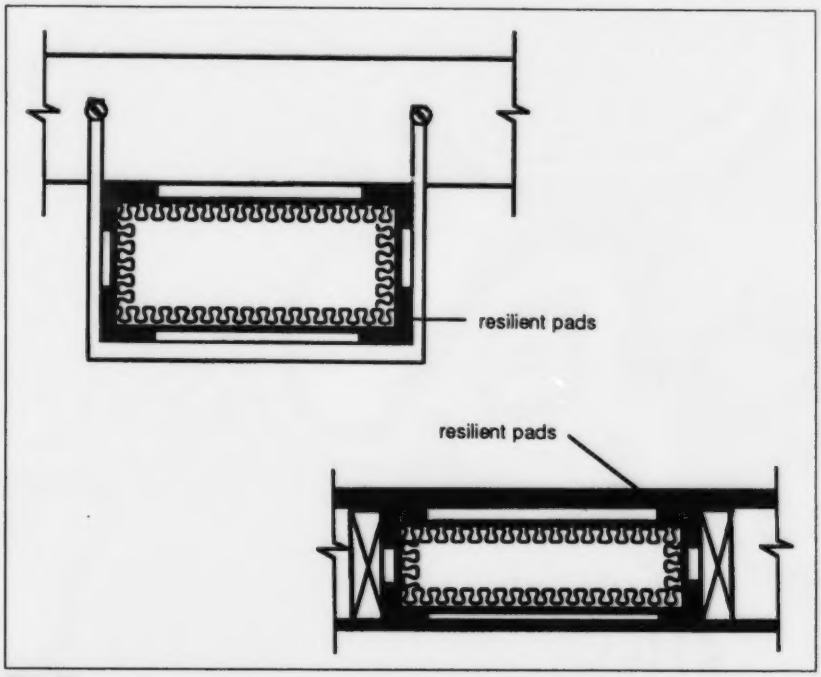

Fig. 29

Problem Noisy ventilation equipment.

Cause Propeller fan used.

Solutions

- Use a higher quality fan. Squirrel-cage fans are usually quieter.
- Move the fan away from the living area. It is preferable to install the fan in the attic or the basement and run the ducts from the fan to the kitchen or bathroom.

Cause Ducts are carrying the sound.

Solution

- Install a flexible coupling between the ducts and the ventilation equipment.

Cause Ventilation equipment connected directly to structure.

Solution

- Avoid connecting directly to the structure. Mount the equipment (HRV or fan) on vibration isolation blocks (blocks of rubber or springs), available from heating appliance distributors.

Additional Reading

SOURCE	PUBLICATION
Canada Mortgage and Housing Corporation 682 Montréal Road Ottawa, Ontario K1A 0P7	*New Housing and Airport Noise*, NHA 5185 81/05. *Road and Rail Noise: Effects on Housing*, NHA 5156 81/10.
Institute for Research in Construction National Research Council of Canada Ottawa, Ontario K1A 0R6	*Introduction to Building Acoustics*, A.C.C. Warnock, Canadian Building Digest 236, 1985. *Building Science Insight '85.* *Guide to the Most Effective Locations for Smoke Detectors in Residential Buildings*, R.E. Halliwell and M.A. Sultan, Building Practice Note 62, June 1986. *How to Reduce Noise Transmission Between Homes (Apartments)*, A.C.C. Warnock, Building Practice Note 44, July 1983. *The Soundproof Basement*, A.C.C. Warnock, Building Practice Note 25, December 1981. *Controlling Sound Transmission into Buildings*, J.D. Quirt, Building Practice Note 56, September 1985. *Factors Affecting Sound Transmission Loss*, A.C.C. Warnock, Canadian Building Digest 239, July 1985.